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ANALYSIS OF DEMANDS ON THE LONG BEACH NAVAL SHIPYARD

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In developing a system for allocating manpower resources in the Navy, major emphasis has been placed on the design of an input-output model to forecast the workload of shore activities, based upon the size and distribution of the fleet. To determine the feasibility of input-output analysis for operational use, a full-scale model of the ~~Eleventh~~ 11th Naval District is being developed. The structure of input-output analysis requires data on the work output of each

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shore activity and its destination in the fleet and other shore activities. In addition, the demands by the fleet must be disaggregated by ship type, movement, and status.

A major effort underway is the collection and organization of data and the empirical analysis of the fleet-shore workload demand network, focusing on 12 major shore activities in the Eleventh Naval District. This report is concerned with the analysis of workload demand on one of ~~these~~ the District's 12 major shore activities--the Long Beach Naval Shipyard (LBSY).

The structure of demands on LBSY ~~the Long Beach Naval Shipyard~~ was analyzed by using Naval shipyard workload data that provided a monthly status report (in terms of man-days expended) on all work being performed on each ship. The data base was used to determine the configuration of total workload and the differences in demand among repair categories and among ship types, as well as changes in demand over time.

FOREWORD

The research and development effort described in this report was conducted in support of the Fleet Impact on Shore Requirements project (formerly entitled Manpower Requirements and Resources Control System (MARRCS)), a subproject under Advanced Development Z0109-PN, Manpower Requirements Development Systems. The overall objective of this subproject is to test and evaluate technologies directed toward improved manpower resources management. The primary effort to date has been an empirical study of the fleet and shore demands placed on major shore activities in the Eleventh Naval District, with the objective of developing an input-output model of the fleet-support demand network. This report focuses on one of those major shore activities, the Long Beach Naval Shipyard.

Acknowledgements are due Mr. R. Patterson (Production Control Branch) and Mr. M. Petrich (Industrial Planning Division) of the Long Beach Naval Shipyard, and CAPT J. I. Webb and Mr. P. Joosten (Work and Resources Planning Division) of the Naval Sea Systems Command for their assistance and guidance. The entire staff at the Long Beach Naval Shipyard and NAVSEA were extremely helpful and cooperative throughout the data collection and analysis stages of this study.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

A system for determining Navy manpower requirements and allocating manpower resources must be based on the workload and economic relations among individual shore-support activities. The demand network that links shore activities to one another, and to the fleet, constitutes the economic system of the Navy. To represent this network structure, an input-output (I/O) model of the Eleventh Naval District is being developed to forecast the workload of shore activities, based on the size and distribution of the fleet. Since a large data base for an I/O model is essential, workload data must be collected, organized, and analyzed.

Objective

The purpose of this research effort was to analyze workload demands placed on the Long Beach Naval Shipyard (LBSY) by the fleet.

Approach

The structure of demands on LBSY was analyzed by using naval shipyard workload data that provided a monthly status report (in terms of man-days expended) on all work being performed on each ship. The data base was used to determine the distribution of total workload and the differences in demand among repair categories and among ship types, as well as changes in demand over time.

Results

1. LBSY currently overhauls and repairs 18 to 20 Navy ships per year.

2. Fleet demand on LBSY was found to differ by ship type and by the kind of repair work performed.

3. Regular overhaul is the largest repair category at LBSY, consuming approximately 75 percent of total yearly workload.

4. Guided Missile Cruisers (CGs), Guided Missile Destroyers (DDGs), Frigates (FFs), Conventional Destroyers (DDs), and Attack Aircraft Carriers (CVAs) commanded the largest share of workload among all ship types.

5. Average demand rates (mean man-days expended per repair) for ship types in the regular overhaul category have been substantially higher since 1973 due to a reduction in fleet size by inactivation, the end of the Vietnam War, and a substantial increase in funding for ship modernization and repair.

6. The source and intensity of unscheduled workload demand is very difficult to forecast. However, given a set of probabilities that a ship type will require unscheduled repairs, expected unscheduled workload can be estimated.

7. True fleet demand on LBSY is not necessarily represented by the actual workload at LBSY. Fleet demand and shipyard workload are constrained by resource limitations and administrative regulations.

Conclusions

1. Naval shipyard workload data are available to measure fleet demands on shipyards in terms of man-days expended per repair. This data will easily conform to an I/O framework.

2. The ship type and the kind of repair performed affected demands placed on LBSY. An I/O model that includes these demands must stress the differences in workload among different ship types and repair categories.

3. Despite the large number of different ships appearing at LBSY over the observed period, these can be aggregated by ship type into 29 manageable sectors in an I/O model. This will reduce problems of computer solvability and data management.

4. This analysis will result in the construction of I/O coefficients for the LBSY sector of the full-scale 11ND I/O model.

Recommendation

This analysis should be extended to include all eight naval shipyards. Close liaison should be maintained with the Naval Sea Systems Command when the entire naval shipyard system is incorporated into the Navy-wide I/O model.

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INTRODUCTION

Problem

The design of a system to determine manpower requirements and to allocate manpower resources has emphasized the development of an input-output (I/O) model. The purpose of such a model is to forecast the workload of shore activities, based on the size and configuration of the fleet, and then to derive manpower requirements from the workload forecasts. The I/O structure will link the activities of the fleet to each individual shore-support activity, and also indicate linkages among shore-support activities. With the interconnections among fleet and shore activities identified, methods can be developed to quantitatively measure the relationship of workload demands on the operating forces and shore-supporting activities.

The I/O model may be able to answer a wide variety of Navy management questions, such as:

1. For changes in fleet size or mix, what shifts in workload can be expected at each shore activity?

2. What is the impact of changes in the shore establishment on the level of fleet support?

3. If ships are transferred from one homeport to another, what will be the effect on activities at each port?

A prototype I/O model was constructed for 28 sectors in the Eleventh Naval District using logistics data. Although the data were somewhat spotty and inaccurate, this model demonstrated the applicability of the I/O technique in forecasting Navy manpower requirements (Sorensen & Willis, Note 1).

At present, a full-scale model of the Eleventh Naval District is being developed to test the feasibility of I/O analysis for operational use. In developing this model, data must be obtained on the output of each shore activity and its destination in the fleet and other shore activities. Further, fleet demands must be broken out by ship type, movement, and status. Thus, current efforts are being devoted to the collection, organization, and analysis of data for use in describing a fleet-support demand network.

This data analysis effort is concentrating on the workload demands placed on 12 shore activities in the 11ND.[1] These activities were selected for their wide range of functions, outputs, and data problems, their manpower intensity, and their direct and indirect linkages to the fleet. Furthermore, they comprise nearly 45 percent of the total workforce in the 11ND.

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[1]These activities include the Long Beach Naval Shipyard, San Diego; Naval Supply Center, San Diego; Naval Air Rework Facility, North Island; Naval Air Stations, North Island and Miramar; Naval Regional Medical Center, San Diego; Naval Training Center, San Diego; Naval Station, San Diego; Public Works Center, San Diego; Naval Electronics Laboratory Center, San Diego; Naval Electronic Systems Engineering Command, San Diego; and the Development and Training Center, San Diego.

Purpose

The purpose of this effort was to analyze workload demand on the Long Beach Naval Shipyard (LBSY),[2] which is currently responsible for the maintenance, alteration, repair, and overhaul of 18 to 20 Navy ships per year. LBSY, the third largest of the eight naval shipyards, employs over 7,000 civilians. The sole source of demand on LBSY is the fleet.

Background Information on Naval Shipyard Workload Allocation

U.S. Navy ships have prescribed overhaul, maintenance, conversion, and modernization schedules, as well as unexpected repair requirements. Requests for this work represent the fleet's demands on the naval shipyard system. The question is how fleet demand reaches a particular shipyard such as LBSY.

The Chief of Naval Operations (CNO) is responsible for maintaining the readiness of Navy forces, and the Chief of Naval Material (CNM), for meeting the material support needs of Navy operating forces, including the maintenance, alteration, repair, and overhaul of ships. CNO coordinates the efforts of the Navy's operating forces with those of CNM in regard to the maintenance and improvement of ships.

The day-to-day management of the manpower resources of the naval shipyards is the basic function of the Work and Resources Planning Division of the Naval Sea Systems Command (NAVSEA 071), as designated by CNM. The Scheduling Branch in this division is responsible for assigning ships to naval and private shipyards so that present and future facilities and equipment are used to maximum efficiency. This is done by looking at each ship individually, and implementing a schedule to accomplish the work based on (1) the kind of work to be done and the corresponding individual shipyard technical specifications, (2) the ship's priority relative to others, and (3) the ship's tentative funding. Although such factors as homeports, dock requirements and drydock capacities, and shipyard manpower level are also considered, the key element is probably funding. Once a customer's tentative funding for the fiscal year is known, the dollars allocated for repair, overhaul and/or conversion, etc. are translated to productive "man-days," utilizing a productive man-day factor unique to the shipyard to be involved. The work is then distributed across the eight naval shipyards and numerous private facilities.

After the tentative schedule has been devised for the upcoming fiscal year, there are several negotiating sessions involving NAVSEA, OPNAV, and fleet staffs. The result is a production workload forecast that is updated by revised customer funding plans, altered shipyard workload capabilities, and amended workload packages and modernization programs.

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[2]This is the second in a series of reports from the empirical study of demands placed on 11ND shore activities. The first was an analysis of demands on the Naval Supply Center, San Diego (Blanco, 1976).

APPROACH

Data Sources and Initial Processing

Statistical analysis of the workload demand placed on LBSY by the fleet requires a large data base. The primary data source concerning naval shipyard workload is the Planned Workload and Employment Report (PWER). The PWERs, which provide a monthly status (in terms of man-days expended) on all work being performed by hull number, were obtained from the Production Control Branch at LBSY. PWERs were collected and analyzed for the period June 1969 to April 1976.

"Man-days expended" in overhaul, repair, etc. was selected as the workload measure rather than such alternatives as "the number of ships in the yard" for several reasons. For example, the latter does not distinguish between the workload required to complete a regular overhaul on a guided missile cruiser and minor repairs on a small frigate. Also, the Long Beach Naval Shipyard and NAVSEA use "man-days expended" as their workload indicator for planning and scheduling.

Because the PWER permits an analysis of the demand on LBSY in terms of individual customers, the data can be used to determine the feasibility of grouping ships by type, the proportion of the total demand accruing to each ship type and repair category, the differences in workload for different types of repair (overhaul, post-shakedown, fitting outs, etc.) and different ship types, and the change in demand over time for ship customers. If ships of the same type have similar demand patterns, then the fleet can be represented by ship types in an I/O model and each type would have a final demand consisting of the number of ships in the type. When the data are included in an I/O model with data from other activities, the importance of second and higher order effects can then be determined.

Initial processing involved calculating the distribution of total shipyard workload by the kind of repair work performed and by ship type. The former required computing the total man-day expenditure for individual ships for each kind of repair, while the latter meant aggregating those ships by type. Finally, the demands of each ship type for each kind of repair received were isolated.

Analysis of Demand

The analysis of demand on LBSY focused on ship type and the kind of repair performed as indicators of the source and intensity of demand. Fleet demand was observed over a 7-year period to test the effects of the modification of ship's funding, changes in the size of the fleet, and alterations in workload attributable to the transition from wartime to peacetime.

Average demand rates and standard deviations were calculated for each type represented in a repair category. This involved looking at 30 ship types, 292 individual ships, and 8 different repair categories. The demand rate for a ship in a repair category was the total man-days expended during the repair cycle. The demand rates for all ships within a given type and repair category were averaged to obtain an average man-day expenditure for a ship in that type and repair category. The regular overhaul computations were done for two distinct time periods, 1969-1972 and 1973-1976.

Of equal importance to total workload expended during a repair cycle is the distribution of the workload over the repair cycle. The average percentage contribution to total workload for each month[3] of a regular overhaul (RO) cycle was calculated for four of the largest regular overhaul customers (CGs, DDGs, FFs, and FFGs).

Forecasting Unscheduled Demand

The broad variation in the type of repairs, as well as the uncertainty of when they will occur, make forecasting the workload of unscheduled repairs very difficult. Nevertheless, a method for projecting workload requirements for unscheduled restricted availabilities (RA) has been developed. This method is based on a table containing the probabilities that a ship type can be expected in the shipyard for an unscheduled repair requiring berthing and shore support. These probabilities were obtained from the Berthing Utility Requirements File (BURF), a subprogram of NAVSEA's Long Range Planning System (LRPS), and were developed from experience and expected developments. They reflect the age distribution of the ships in a ship type and the recent incidences of repair and overhaul performed on a ship type. Expected total RA workload levels were calculated for 1976 by (1) multiplying the assigned probability by an average historical RA value for the corresponding ship type, (2) multiplying this figure by the average number of ships in that type that have frequented LBSY per year for any type of work (this captures the fleet mix that uses LBSY), and (3) summing over all ship types. The results indicate an anticipated man-day expenditure of 25,000 for 1976. Through the first 6 months of 1976, approximately 16,000 man-days had actually been expended for RAs, about 3,000 more man-days than anticipated.

An alternative method would be to use an average of total RA workload per year. However, this method yielded an estimate over 6,000 man-days higher than the actual RA total for the first half of 1976.

Constrained vs. Unconstrained Workload and Demand

The output of a naval shipyard is not entirely demand-driven, but is also constrained by resource restrictions such as ship's funding, manpower ceilings, and skill limitations, as well as limited space and regulations. Therefore, actual workload at LBSY during a month does not necessarily represent true demand by the fleet on that yard.

The primary limitation on demand is an individual ship's budget allocation for overhaul and repair. Naval shipyards, like all naval industrial facilities, operate on a reimbursement basis--a ship "buys" what work it can. Lack of adequate funding may mean delaying a ship's scheduled overhaul or performing less work than it needs.

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[3]Often a ship will enter a shipyard late in a month and/or depart early in another month. To avoid including very small observations, a shipyard "month" was considered as 15 or more days in the yard during the calendar month.

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A shipyard's workload is constrained by manpower ceilings. Shipwork that requires workload beyond these limits is either delayed, "farmed-out" to other yards, or never completed. Skill deficiencies (for example, pipefitters and boilermakers) in many yards reduce the speed at which a ship passes through the various production shops. Limited berthing and drydocking space can also produce queues. Finally, DoD Instruction 4151.1 requires that at least 30 percent of new construction, alterations, repairs, and overhauls be done in private shipyards. Some fleet demand may go unattended when private yards are not equipped to handle the load or the configuration of the work that accompanies it, or when they lack the required skills.

Like a Navy calibration laboratory, where time becomes a factor since a ship must be calibrated before deployment (Blanco, Bokesch, & Sorensen, Note 2), a naval shipyard must operate within the constraints of available resources, space, and administrative regulations and policies, as well as a tight operations schedule. Consequently, a shipyard is forced to set priorities, and certain low priority tasks may never be completed.

This suggests that an effective Navy manpower planning system cannot ignore the constraints placed on demand and workload at shore-support establishments. In this regard, empirical evidence such as "the number of ships bow-waved per year" (overhaul deferred) and/or "total man-days bow-waved" can be used to indicate the amount of workload demand placed on the naval shipyard system but not satisfied.

RESULTS

Data Sources and Initial Processing

Analysis of the Planned Workload and Employment Reports at the Long Beach Naval Shipyard showed that 292 ships were serviced from June 1969 to April 1976. The number of ships serviced per year has declined steadily, from an average of 61 during 1969-1972 to an average of 18 since 1973. However, total workload per year has increased slightly over this period, from an average of approximately 695,000 man-days in 1969-1972 to 760,000 since 1973.

Workload by Repair Category

The kinds of repair observed at the Long Beach Naval Shipyard (LBNY) were (1) regular overhauls (ROs), (2) postshakedown availabilities and fitting outs (PSAs/FOs), (3) scheduled restricted availabilities (SRAs), (4) unscheduled restricted availabilities (RAs), (5) inactivations (INAs), (6) conversions (CONs), and (7) complex overhauls (COHs). Results obtained by computing the total man-day expenditure for individual ships for each type of repair are shown in Table 1. As shown, the largest category of repair--in terms of man-days expended--over the period from 1969 to 1975 is RO. It comprised at least 75 percent of the total workload since 1973. The other repair categories show more fluctuation. For example, until 1973, PSAs/FOs, INAs, CONs, and COHs together contributed an average of 31 percent of the total workload per year. However, since 1973, very little of this kind of work has been done. Alternatively, SRAs do not appear before 1973, but, since that time, they have claimed as much as 17 percent of the total workload.

Table 1

Percent of Workload by Repair Category, 1969-1975,
Long Beach Naval Shipyard

Repair Category	Year 1969	1970	1971	1972	1973	1974	1975
Regular Overhaul (RO)	68	50	79	56	78	83	75
Postshakedown Availability and Fitting Out (PSA/FO)	7	16	16	22	10	0	0
Scheduled Restricted Availability (SRA)	0	0	0	0	6	13	17
Unscheduled Restricted Availability (RA)	5	9	4	6	6	4	8
Inactivation (INA), Conversion (CON), and Complex Overhaul (COH)	20	25	1	16	0	0	0

Workload by Ship Type

When ships were aggregated by type, it was found that LBSY's largest customers from 1969 through 1975 were destroyers (DDs), guided missile destroyers (DDGs), frigates (FFs), guided missile cruisers (CGs), and attack aircraft carriers (CVAs), in that order. In 1975, these five ship types accounted for over 79 percent of the total workload. However, as Table 2 shows, the proportion of workload accruing to each ship type has changed dramatically during the observed period. For example, since 1969, DDGs and DDs have exchanged positions of prominence at LBSY.

It is no coincidence that the workload mix at LBSY is dominated by these ship types since distribution of total navy shipwork considers primarily the specializations of the various shipyards. The composition of the fleet is such that shipyards must provide a large and varied number of specialities and skills. In scheduling, every effort is made to assign shipwork on the basis of specialization, decreasing the need for duplication of work and facilities. LBSY has been and is scheduled to remain quite specialized in overhaul, repair, and modernization of anti-aircraft warfare (AAW), anti-submarine warfare (ASW), and amphibious and auxiliary ships (AMX). Ships under these three specializations accounted for over 90 percent of the workload at LBSY during the sample period.

When the demands of each ship type for each kind of repair received were isolated, it was found that four ship types (i.e., DDGs, DDs, FFs, and CGs) a total of 69 ships, constituted 63 percent of the total regular overhaul workload at LBSY during the observed period. The total man-days expended on these ship types are shown in Table 3.

While postshakedowns and fitting outs comprised an average of over 13 percent of the total shipyard workload per year, FFs dominated these availabilities with nearly 63 percent of the workload. Scheduled restricted availabilities, 17 percent of the total shipwork in 1975, was predominately reserved for modernization of CVAs. Three such carriers made up 99.5 percent of the SRA workload.

In addition to the scheduled ship workload in Naval shipyards, there is work on unscheduled availabilities (manufacturing, fleet equipment and "component" repair). Of the twenty ship types represented under restricted availabilities, four (i.e., DDs, CGNs, DDGs, and PGs) combined to make up 54 percent of the unscheduled repair workload during the observed period.[4]

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[4]"Restricted availability" (RA) is industrial work between overhauls that was <u>not</u> previously scheduled by OPNAV. However, drydock space and manpower are intentionally not assigned to allow for these unexpected repairs. During an RA, the ship is actually in the shipyard, while during a "technical availability" (TA), a ship's equipment is repaired in the yard, but the ship is not present.

Table 2

Percent of Workload by Ship Type, 1969-1975,
Long Beach Naval Shipyard

	Year						
Ship Type	1969	1970	1971	1972	1973	1974	1975
AD	0.0	0.5	0.0	2.8	0.0	0.0	0.0
AFS	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AH	0.0	1.5	0.0	0.0	0.0	0.0	0.0
AO	3.5	3.9	3.8	2.6	0.0	0.0	0.0
AOE	0.0	0.7	6.7	0.0	0.0	0.0	0.0
AOR	2.6	0.5	0.9	1.8	0.0	7.0	0.0
APB	0.2	0.0	0.0	0.0	0.0	0.0	0.0
AR	2.4	0.0	0.0	0.0	0.0	2.2	0.0
ASR	0.0	0.0	0.0	0.0	0.0	0.2	4.0
AVM	0.0	0.0	0.4	6.9	1.2	0.0	0.5
CA	9.8	0.0	0.0	0.0	0.0	0.0	0.0
CG	0.0	7.3	6.4	17.6	13.8	11.3	9.9
CGN	0.0	0.5	1.1	1.5	2.5	0.0	0.0
CVA	0.0	0.0	0.0	0.0	6.0	12.8	22.9
CVS	19.0	0.0	0.0	0.0	0.0	0.0	0.0
DD	30.8	43.5	26.6	16.5	0.5	12.4	0.7
DDG	6.7	7.8	19.2	5.4	24.1	19.5	34.3
FF	3.4	9.1	16.7	24.8	27.1	21.5	11.6
FFG	0.5	7.2	4.0	0.0	9.0	0.0	0.0
LCC	2.9	0.0	0.8	0.0	0.0	0.0	8.9
LKA	0.6	0.7	0.0	0.0	0.0	0.0	0.3
LPD	9.8	1.5	0.2	4.4	5.1	5.9	0.4
LPH	6.0	1.3	0.0	10.8	10.0	0.0	0.0
LSD	0.0	5.0	4.8	0.1	0.0	7.2	0.6
LST	0.2	4.8	3.9	3.1	0.0	0.0	5.9
MSO	0.7	3.1	0.7	0.3	0.0	0.0	0.0
PG	0.9	0.9	3.7	1.3	0.9	0.0	0.0

Table 3

Largest Regular Overhaul (RO) Customers by Ship Type

Ship Type	Number of Ships in Type	Total Man-days Expended
DDG	18	893,079
DD	31	617,189
FF	15	502,316
CG	5	323,885

Analysis of Demand

As indicated previously, the analysis of demand on LSBY focused on ship type and the kind of repair performed as indicators of the source and intensity of demand. Results of this effort showed that shipyard workload changed noticeably beginning in 1973. That year marked the end of a large inactivation program (i.e., reduced fleet size) and the Vietnam War, as well as a substantial increase in the budget for ship modernization and repair. Together, these events afforded individual ships more man-days in repair. The larger man-day expenditure was necessary to provide Navy ships with the latest offensive, defensive, and communications technologies, to install advanced pollution abatement devices, and to make the ships more comfortable and hospitable for their crews. Appendix A displays the average demand rates for ship types in each repair category. It confirms the general increase in average regular overhaul demand rates beginning in 1973. The other repair categories had less noticeable changes in their demand rates over time.

In general, ships of the same type and repair category had similar demand patterns. However, there were several exceptions. First, for some ship types, there were not enough ships in the data base to conclude that all ships of a type had similar demand patterns. For example, in the RO repair category, there was only one ship observed in each of the AD, AOE, AOR, AR, AVM, CVS, and LST ship types. Similar deficiencies occurred in other repair categories. Second, several ship types have not been serviced at LBSY since 1972 or earlier. It would be misleading to suggest that current demand for those ship types would approximate that of 4 or more years ago. Finally, unscheduled restricted availability (RA) workload is difficult to forecast because of its sporadic occurrence and irregular requirements. Unlike an RO, where there is a standard maintenance package, an RA may range from replacement of a component to collision damage repair.

Some ship types could have been grouped into categories defined by average man-days expended per repair. For example, as regular overhaul customers, CGs and DDGs had average demand rates of 86,037 and 74,353 man-days, respectively. One-way analysis of variance was performed to test the hypothesis that these two ship types have the same mean demand rates as regular overhaul customers.

The results of this test indicated that the hypothesis could be accepted. (Appendix B displays the analysis of variance statistics.) Several other ship types had similar demand rates, but there were so few observations (i.e., ships) that no conclusions about the equality of these rates could be made. Even when average demand rates are the same, it does not follow that these same ship types would fall into an identical demand group for other repair categories or for outputs other than "man-days expended." Consequently, analysis by ship type and repair category was maintained throughout.

When the average percentage contribution to total workload for each month of a regular overhaul (RO) cycle was calculated for CGs, DDGs, FFs, and FFGs, it was found that, while the four ship types differed in average length of an overhaul, as well as actual man-days expended in an overhaul, each had very similar workload distribution characteristics. All four ship types completed at least 60 percent of the shipwork after only one-half of the overhaul cycle, while peak workload occurred in the second to fourth month of an 8- to 11-month cycle. Figure 1 displays the distribution of workload (in percentage terms) over the regular overhaul cycle for these four ship types.

Forecasting Unscheduled Demand

The broad variation in the types of repairs, as well as the uncertainty of when they will occur, makes forecasting the workload for unscheduled repairs very difficult. While the largest unexpected repair customers were Destroyers (DD and DDG), Nuclear Guided Missile Cruisers (CGN), and Patrol Gunboats (PG), we cannot conclude they will dominate restricted availability workload in the future. However, given a set of probabilities that a ship type will need unscheduled repairs, expected total RA workload for 1976 was estimated. The estimate for the first half of 1976 was slightly less (3,000 man-days) than the actual man-day expenditure.

Constrained vs. Unconstrained Workload and Demand

Fleet demand and shipyard workload are constrained by (1) a ship's budget allocation for maintenance, (2) shipyard manpower ceilings, (3) particular skill shortages, (4) berthing and drydocking limitations, and (5) a DoD instruction that requires an "in-house/contract" (naval yard/private yard) workload ratio be carefully maintained. Therefore, actual workload at LBSY during a month or year does not necessarily represent true demand by the fleet on that yard.

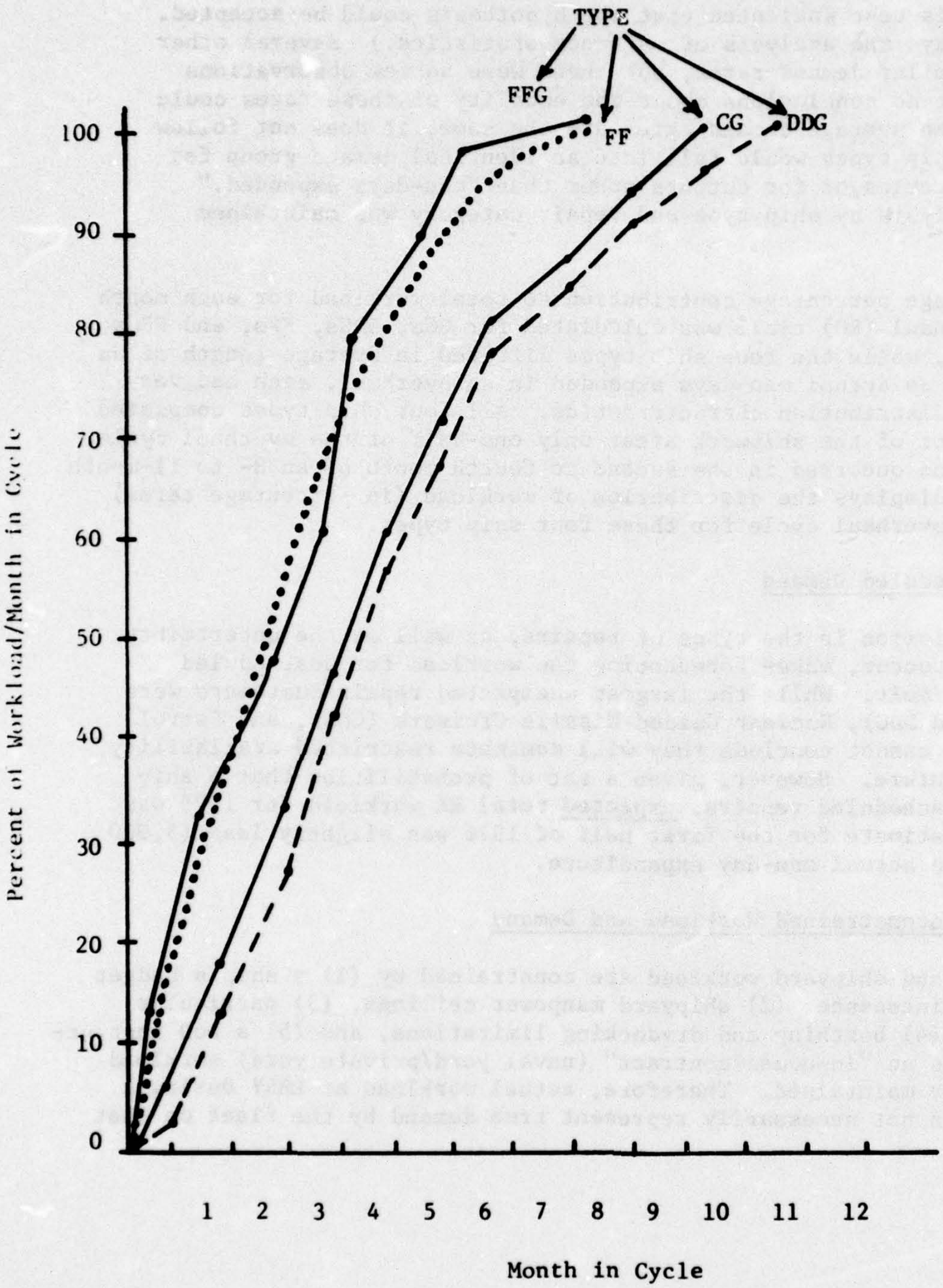

Figure 1. Cumulative percentage workload distribution by month in regular overhaul cycle for selected ship types.

CONCLUSIONS

The analysis of demands on the Long Beach Naval Shipyard permits some general conclusions on the feasibility of building an input-output (I/O) model of the fleet-support demand network.

1. Data exist in the Naval shipyard system to measure fleet demands on shipyards in terms of man-days expended per availability. Although these data will fit into an I/O framework, analysis of the data is a laborious, time-consuming task. Close working relationships with members of NAVSEA's Work and Resources Planning Division and the LBSY Production Control and Advanced Planning Branches were essential in interpreting the data.

2. With computer limitations and problems of data manageability, the number of sectors that can be handled effectively in an I/O model is an important question. While LBSY had 292 customers from June 1969 to April 1976, these can be aggregated by ship types into 29 manageable sectors. Whether those customers (ship types) will also turn out to be the major fleet sectors in a more comprehensive I/O model remains to be determined.

3. Since ship type and the kind of work performed clearly affected the demands placed on LBSY, the I/O model must not ignore the differences in workload due to an Attack Aircraft Carrier vs. a Patrol Gunboat, as well as a regular overhaul vs. a minor alteration.

4. The results from this study will be used to develop I/O coefficients for the LBSY sector of the I/O model. The results will be used in combination with other results from analyses of demands of other major shore activities. For example, the I/O coefficient between LBSY and the Naval Supply Center, San Diego might be measured in units of requisitions per man-days of repair.

RECOMMENDATION

This analysis should be extended to include all eight naval shipyards. Close liaison should be maintained with the Naval Sea Systems Command when the entire naval shipyard system is incorporated into the Navy-wide input-output model.

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APPENDIX A

AVERAGE DEMAND RATES BY REPAIR CATEGORY
LONG BEACH NAVAL SHIPYARD

Table A-1

Average Demand Rates by Repair Category
Long Beach Naval Shipyard

Symbol	Ship Type	Average Demand Rate	Std. Dev.	No. of Ships Observed In Type	Time Period	% Change[a]
	Regular Overhaul (RO), 1969-1972, 1973-1976					
AD	Destroyer Tender	23960	0	1	69-72	
		-	-	-	73-76	NA
AO	Oiler	25617	3584	4	69-72	
		-	-	-	73-76	NA
AOE	Fast Combat Support	52921	0	1	69-72	
		-	-	-	73-76	NA
AOR	Replenishment Oiler	-	-	-	69-72	
		53203	0	1	73-76	NA
AR	Repair Ship	18498	0	1	69-72	
		-	-	-	73-76	NA
AVM	Guided Missile Ship	54242	0	1	69-72	
		-	-	-	73-76	NA
CA	Heavy Cruiser	37514	547	2	69-72	
		-	-		73-76	NA
CG	Guided Missile	32887	9537	2	69-72	
	Cruiser	86037	14393	3	73-76	+89
CVS	Anti-Submarine	135331	0	1	69-72	
	Carrier	-	-	-	73-76	NA
DD	Destroyer	18811	8328	30	69-72	
		78396	0	1	73-76	+123
DDG	Guided Missile	27091	7573	10	69-72	
	Destroyer	74353	6682	8	73-76	+93
FF	Frigate	26164	7545	5	69-72	
		44638	7672	8	73-76	+52
FFG	Guided Missile	24386	6599	3	69-72	
	Frigate	64330	0	1	73-76	+90
LLC	Command Ship	22466	0	1	69-72	
		61608	0	1	73-76	+93

[a] This column indicates the percent change in average demand rates from 1969-1972 to 1973-1976 for ship types with observations in both time periods. This figure is derived by dividing the difference between the two mean demand rates by an average of those rates. This prevents the bias or ambiquity of using an upper or lower base. For example, the calculation for Guided Missile Cruiser (CG) is:

$$\frac{(86037 - 32887)}{(86037 + 32887)/2} = \frac{53150}{59462} = 89\%$$

Table A-1 (Continued)

Symbol	Ship Type	Average Demand Rate	Std. Dev.	No. of Ships Observed In Type	Time Period	% Change[a]
		Regular Overhaul (RO), 1969-1972, 1973-1976				
LPD	Transport Dock	29113	9764	3	69-72	
		43606	8253	2	73-76	+40
LPH	Assault Ship	42701	5898	3	69-72	
		75383	0	1	73-76	+55
LSD	Dock Landing Ship	34971	4326	2	69-72	
		54128	0	1	73-76	+43
LST	Tank Landing Ship	-	-	-	69-72	
		41299	0	1	73-76	NA
MSO	Ocean Minesweeper	5761	1425	3	69-72	
		-	-	-	73-76	NA
PG	Patrol Gunboat	3061	1600	8	69-72	
		-	-	-	73-76	NA
		Post-Shakedown Availability (PSA), 1969-1976				
AOR	Replenishment Oiler	8636	5423	2		
ASR	Submarine Rescue Ship	7539	0	1		
CG	Guided Missile Cruiser	11039	3472	4		
DDG	Guided Missile Destroyer	9660	0	1		
FF	Frigate	14470	7618	18		
FFG	Guided Missile Frigate	3807	0	1		
LCC	Amphibious Command Ship	6644	0	1		
LKA	Amphibious Cargo Ship	2732	0	1		
LPD	Amphibious Transport Ship	18580	9081	2		

[a]This column indicates the percent change in average demand rates from 1969-1972 to 1973-1976 for ship types with observations in both time periods. This figure is derived by dividing the difference between the two mean demand rates by an average of those rates. This prevents the bias or ambiquity of using an upper or lower base. For example, the calculation for Guided Missile Cruiser (CG) is:

$$\frac{(86037 - 32887)}{(86037 + 32887)/2} = \frac{53150}{59462} = 89\%$$

Table A-1 (Continued)

Symbol	Ship Type	Average Demand Rate	Std. Dev.	No. of Ships Observed In Type	Time Period	% Change[a]
	Post-Shakedown Availability (PSA), 1969-1976 (Continued)					
LPH	Amphibious Assault Ship	8295	0	1		
LST	Tank Landing Ship	4567	1283	8		
MSO	Ocean Minesweepers	1357	545	3		
PG	Patrol Gunboat	851	427	9		
	Fitting Out (FO), 1969-1976					
FF	Frigate	3249	1475	10		
LST	Tank Landing Ship	3333	897	16		
MSO	Ocean Minesweepers	776	155	5		
	Scheduled Restricted Availability (SRA/ESRA), 1969-1976					
ASR	Submarine Rescue Ship	1232	0	1		
CVA	Attack Aircraft Carrier	97230	47774	3		
	Inactivation (INA), 1969-1976					
AD	Destroyer Tender	3360	0	1		
AH	Hospital Ship	10280	0	1		
APB	Self-Propelled Barracks Ship	1349	0	1		
CVS	Anti-Submarine Aircraft Carrier	9885	0	1		
DD	Destroyer	2148	925	8		
	Conversion (CON), 1969-1976					
DD	Destroyer	138015	3192	2		
	Complex Overhaul (COH), 1969-1976					
CG	Guided Missile Cruiser	136915	0	1		

Table A-1 (Continued)

Symbol	Ship Type	Average Demand Rate	Std. Dev.	No. of Ships Observed In Type	Time Period	% Change[a]
Unscheduled Restricted Availability (RA), 1969-1976						
AO	Oiler	2918	0	1		
AOE	Fast Combat Support Ship	3838	1375	2		
AOR	Replenishment Oiler	2782	684	3		
ASR	Submarine Rescue Ship	20813	0	1		
AVM	Guided Missile Ship	5055	2792	4		
CG	Guided Missile Cruiser	3485	290	3		
CGN	Guided Missile Cruiser, Nuclear	5751	3616	8		
DD	Destroyer	4084	3783	14		
DDG	Guided Missile Destroyer	9036	9463	5		
FF	Frigate	3051	2414	6		
FFG	Guided Missile Frigate	3107	590	3		
LKA	Amphibious Cargo Ship	2739	1522	3		
LPD	Amphibious Transport Dock	2212	1256	2		
LPH	Amphibious Assault Ship	6284	6886	2		
LSD	Dock Landing Ship	403	0	1		
MSO	Ocean Minesweepers	2543	516	3		
PG	Patrol Gunboat	3129	2442	10		
SS	Submarine	7326	0	1		

APPENDIX B

ANALYSIS OF VARIANCE STATISTICS

ANALYSIS OF VARIANCE STATISTICS

One-way analysis of variance was performed to test the null hypothesis that the mean demand rates for Guided Missile Cruisers (CGs) and Guided Missile Destroyers (DDGs) as regular overhaul customers were equal. Analysis of variance tests the variability of the combined data. If the null hypothesis is true, then all variability in the demand rate data is due to chance. However, if it is not true, then part of the variability is attributable to the differences between the means of the CG and DDG demand rates.

In a one-way analysis of variance, the total sum of squares, SST, is separated into two parts, an error sum of squares, SSE (variance due to chance), and a "treatment" sum of squares, SS(Tr) (variance due to differences in mean demand rates), where SST = SSE + SS(Tr) (Freund, 1971). Table B-1 presents the results of the calculations to determine the F value for this problem. The calculated F Value (.80) is less than the critical $F_{.05,1,8}(5.32)$. Therefore, the null hypothesis that the mean demand rates of CG and DDG as regular overhaul customers are equal cannot be rejected at the 99 percent confidence level.

Table B-1

Results of Analysis of Variance Test of Similarity of Ship Type Demand Rates

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F
Treatments	k-1	68,257,928	$\frac{68,257,928}{1}$ =	$\frac{68,257,928}{85,288,684}$ =
	1		68,257,964	.80
Error	N-k	682,309,478	$\frac{682,309,478}{8}$ =	
	8		85,288,684	
Total	10			
	N-1			

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